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The Effect of On/Off Indicator Design on State Confusion, Preference, and Response Time Performance

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
HCI	Human-Computer Interface
LESC	Lockheed Engineering & Sciences Company
NASA	National Aeronautics and Space Administration

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THE EFFECT OF ON/OFF INDICATOR DESIGN ON STATE CONFUSION, PREFERENCE, AND RESPONSE TIME PERFORMANCE

EXECUTIVE SUMMARY

An important Human Factors design challenge is the translation of human-machine interfaces from primarily hardware systems to primarily software systems. Environments such as aircraft cockpits, automobile instrument panels and manufacturing control panels have become increasingly software-based. The hardware buttons, switches and lights used in the past are being replaced with on-screen software-based graphical representations (icons) of these hardware objects.

This hardware-to-software conversion offers both advantages and disadvantages within the human-computer interface (HCI). In the present study, the HCI challenge is the display of objects that do not lend themselves easily to graphical representation (e.g., indicator lights). This study investigates five designs of software-based ON/OFF indicators in a hypothetical Space Station Power System monitoring task. The hardware equivalent of the indicators used in the present study is the traditional indicator light that illuminates an "ON" label or an "OFF" label. Coding methods used to represent the active state (i.e., "ON" or "OFF") were reverse video, color, frame, check or reverse video with check. Display background color (i.e., black, white) was also varied. Subjects made judgments concerning the state of indicators that resulted in very low error rates and high percentages of agreement across indicator designs. Response time measures for each of the five

indicator designs did not differ significantly, although subjects reported that color was the best communicator. The impact of these results on indicator design is discussed.

THE EFFECT OF ON/OFF INDICATOR DESIGN ON STATE CONFUSION, PREFERENCE, AND RESPONSE TIME PERFORMANCE

1.0 INTRODUCTION

With the increasing computerization of traditionally mechanical systems, environments such as aircraft cockpits, power plant control panels and even automobile instrument panels have become increasingly software-based. While providing many advantages such as flexibility and conservation of space, this modernization of interfaces may be a mixed blessing. Little is known about translating a hardware interface to a software representation. Although there has been a reasonable amount of human factors research dedicated to investigating the perception and use of status indicators, this research has been focused primarily on hardware implementations (e.g., lights, knobs, and dials), and not the software representation of this information. One analog to this problem does exist and has received some attention: the conversion of hard copy textual information into a software representation.

Shneiderman (Ref. 4) has listed the advantages and disadvantages of making technical manuals available on the computer, as opposed to traditional hard copy manuals. Advantages of the computerized display of information include the capability to easily update information, the capability to present information graphically or through animation, and the compactness of the physical area required for the information

display (i.e., monitor size). Disadvantages of computer-based displays include the comparatively poorer readability of display screens over hard copy, and the lower amount of information available per unit (display screen versus printed page).

A challenge specific to the conversion from hardware to software displays is the software representation of objects or attributes that are not readily representable in a graphical computer display. This challenge may take the form of the conversion of hardware ON/OFF lights that represent system status to the software representations of these indicator lights. Hardware ON/OFF lights generally consist of one of three designs: (1) two separately labeled indicator lights (one labelled "ON" and one labeled "OFF"), (2) one indicator light that represents "ON" when illuminated and "OFF" when unilluminated, and (3) one indicator light with two areas, one labeled "ON" and one labeled "OFF". The advantage to the last design is that it provides for quick and easy scanning. Position differences and the overall pattern formed by the lights make the identification of off-nominal situations less difficult (illustrated by the ON/OFF indicators shown in Figure 1).

Lights that are turned "ON" are generally represented two-dimensionally on hard-copy paper versions through the use of color or reverse video (as in Figure 1). Is this solution a viable one for the software-based display of indicator lights, or should the display designer adopt a non-traditional solution (e.g., use of checks or frames) in lieu of attempting to replicate the hardware design? These are the kinds of design questions facing display designers of interfaces for systems that have traditionally been hardware-based.

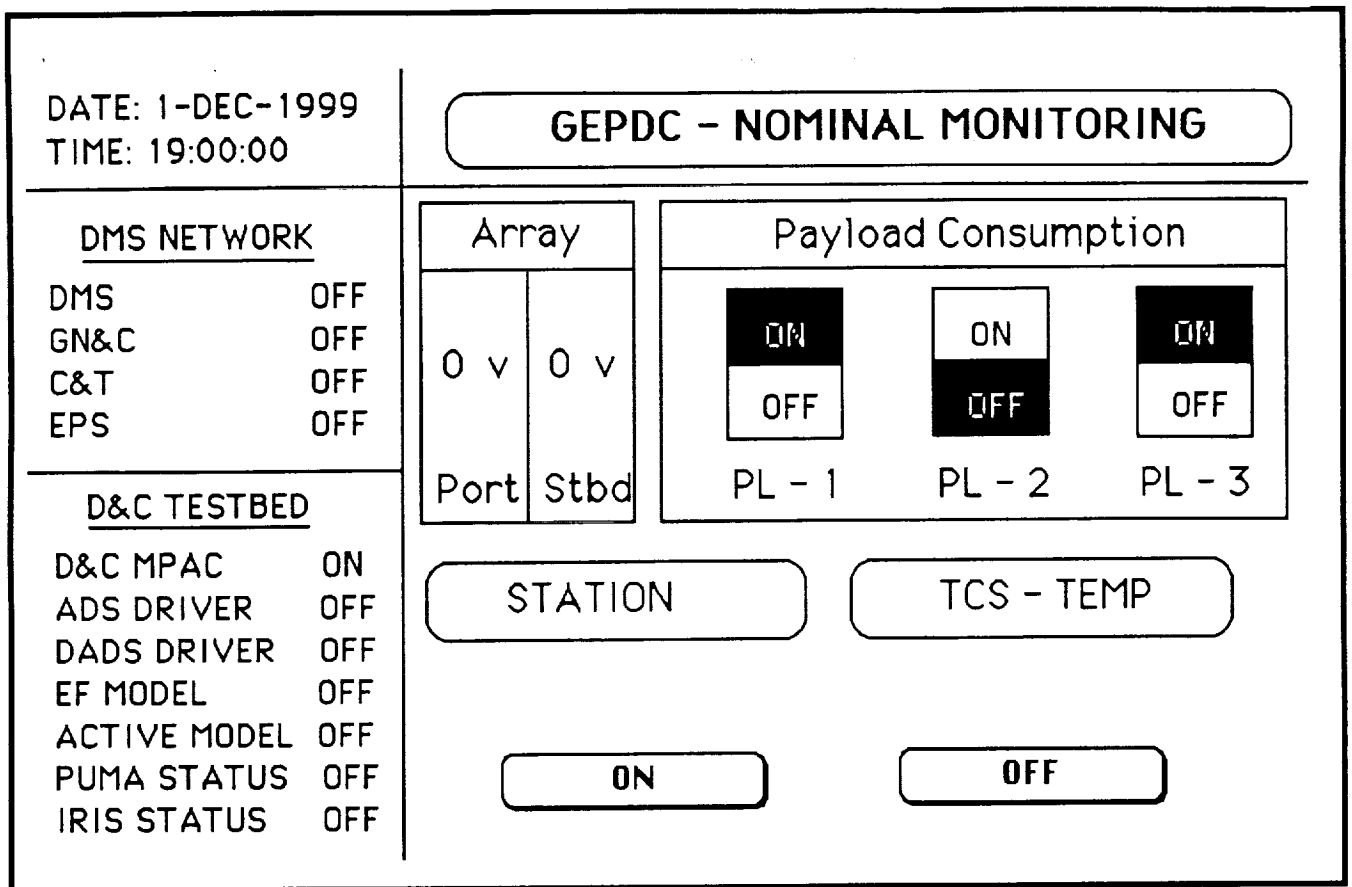


Figure 1. Example of an indicator display.

An example of the hardware-to-software interface migration problem is the design of the human-computer interface for Space Station Freedom. All past and present spacecraft interfaces have been primarily hardware-based. For example, the Space Shuttle workspace consists of approximately 2,000 switches and indicators. The interface for Space Station Freedom will be almost entirely software-based. Controls that have traditionally been switches to be manually flipped will now be software switches or buttons that will be activated via a direct manipulation control device (e.g., trackball). Indicators that have been represented by a bank of lights will now be

represented in a software display. The design of these types of software indicators is the challenge addressed in the present study.

The criticality of optimal coding for ON/OFF indicators is obvious. If a binary indicator (e.g., "ON", "OFF") is misinterpreted, a conclusion in direct opposition to the truth is made. At best, a misreading of the indicator may result in lost time and wasted effort; at worst, such a confusion of indicator state may result in costly, possibly dangerous decisions and actions. Crew member judgments or assessments about the health of a system rely on the correct interpretation of these indicators. The importance of optimal coding in these situations cannot be overstated. For this reason, standards exist in the space program as well as in other settings regarding binary coded indicators (e.g., Ref. 2). Unfortunately, although most standards documents maintain that binary coding must be unambiguous, the method for achieving this is often unspecified.

The impetus for the present work was a noted difference in individuals' perception of a software display showing the ON/OFF state of indicators coded with reverse video (the typical paper representation). Several reviewers of a preliminary Space Station prototype display expressed confusion over the actual state (i.e., ON or OFF) of indicators in which the active state was coded with reverse video. This confusion had not been noted with preliminary paper versions of the displays. The goal of the present work was to determine if the reverse video coding was actually a problem and, more globally, which of a number of ON/OFF indicator designs is optimal for communicating status information on a software display. Display

background color was examined in conjunction with the indicator designs.

Since this study was spawned from subjective report, and there is evidence in the human performance literature that subjective report of performance does not always match actual objective performance (Ref. 3), subjective ratings of indicator ability to communicate were collected for analysis in addition to the traditional response and response time measures. This allowed measurement not only of preference for the particular indicators studied, but also allowed comparison of the objective and subjective reports of performance.

2.0 METHOD

2.1 Subjects

Ten Lockheed Engineering & Sciences Company (LESC) employees voluntarily participated in the study. All subjects had experience with a computer and a mouse.

2.2 Apparatus and Stimuli

The experiment was conducted on a Macintosh IIx with a 13-inch color monitor. The experiment was programmed in Supercard. Stimuli consisted of five displays, one for each of the five ON/OFF indicator designs. The indicators were embedded in a hypothetical Space Station monitoring display (see Figure 1). The indicators all contained the central rectangular ON/OFF components, but varied in the highlighting

method used to show activation (i.e., "ON" or "OFF"). The five methods (illustrated in Appendix 7.1) included: (1) frame, (2) check, (3) color (cyan blue), (4) reverse video, and (5) reverse video with check. The frame and check display methods represent non-traditional coding while the color and reverse video display methods represent the more traditional coding methods used on paper. The reverse video with check was investigated for a redundancy advantage. All indicator designs were typical representations used in engineering software displays.

Each design was presented on both a black display background and a white display background, creating a total of ten different display stimuli. In the reverse video condition, the highlight was the color opposite the background color. For example, on the white background trials, black was used as the highlight, while on the black background trials, white was the highlight.

2.3 Experimental Task

The experimental task involved the presentation of an initial display querying the status of a particular ON/OFF indicator, followed by a Space Station Power System monitoring display on which the subject was to make a response. The first display contained a question such as, **"What is the current status of the PL-2 indicator?"**. When the subject had read the question and was ready to view the display, the subject clicked on a "Ready" button located below the question. Figure 2 shows an example of the query display. When the "Ready" button was clicked, the monitoring display appeared. The task-relevant portion of the display consisted of a section of three ON/OFF

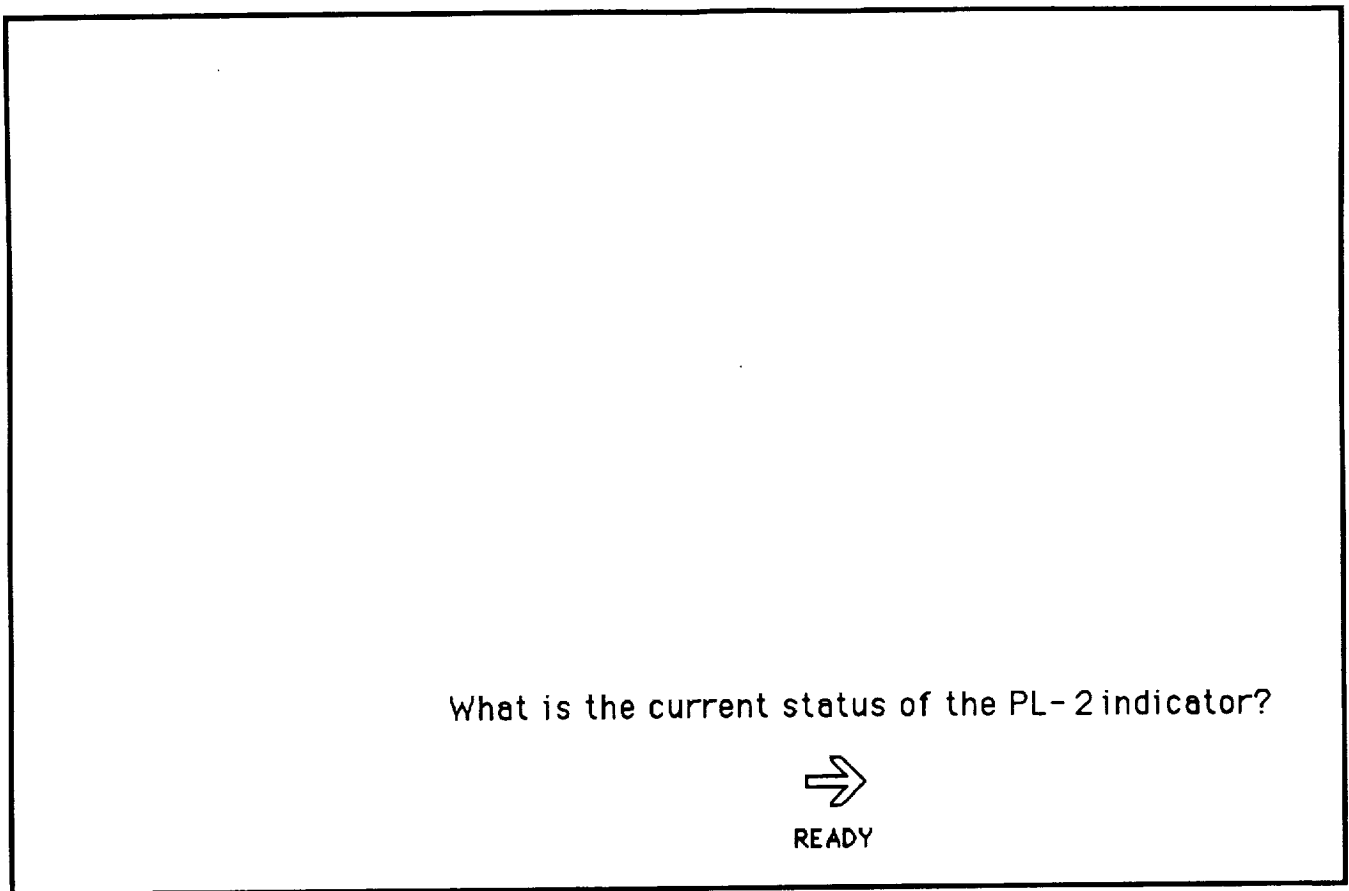


Figure 2. Example of a query display.

indicators labelled "PL-1," "PL-2," and "PL-3" with various combinations of ON/OFF states represented (i.e., sometimes all "ON," sometimes all "OFF," sometimes a mixture of "ON" and "OFF"). Subjects were told that any combination of the indicators could be "ON" or "OFF" during any trial. The placement of the highlights on the three indicators was controlled such that each pattern formed by the three highlights occurred on an equal number of trials.

Two response buttons labeled "ON" and "OFF" were located at the bottom of the display. After scanning the display for the status of the queried indicator, subjects clicked on the "ON" or "OFF" button as

quickly as possible. No feedback was provided to subjects during the experiment concerning the correctness of their response. In order to reduce the motor component of the response time, subjects were instructed not to move the mouse after clicking on the "Ready" button of the query display until they were prepared to answer the indicator question. Leaving the cursor on that point placed the cursor midway between the ON/OFF response buttons. After responding to the indicator screen, the next query display appeared.

2.4 Procedure

In addition to written instructions, subjects were given a practice session consisting of ten trials in order to gain familiarity with the indicator displays and the experimental procedure. Two of each of the five indicator designs were randomly presented during the practice session. After training, subjects began the experimental session and were told to respond as quickly and accurately as possible.

Subjects completed two blocks (240 trials) of performance separated by a rest break. Trials were blocked by background color so subjects received 120 trials on a black background and 120 trials on a white background. The order of the blocks was randomly assigned. Within each background block, subjects received 24 instances of each of the 5 indicator designs. Query displays and indicator designs varied randomly within a block.

After each block, subjects completed an indicator design rating scale for the particular display background (see Appendix 7.1). The rating scale asked subjects to rate the capability of each indicator to

communicate ON/OFF status. At the end of the experiment, subjects completed a general questionnaire that queried preferences for display background color and previous experience with hardware and ON/OFF indicators (see Appendix 7.2). Subjects were debriefed and any questions were answered.

3.0 RESULTS

Three measures of indicator display effectiveness were analyzed: (1) indicator state responses, (2) response times to indicate the state, and (3) subjective ratings of the effectiveness of the indicators. Because the initial impetus for the study involved confusion over indicator state, responses were evaluated for degree of agreement. Response times and subjective ratings served as usability measures. An additional analysis was performed to determine the correlation between subjective rating and performance with each indicator display design.

3.1 Indicator State Analysis

The capability to analyze response data depends upon an objective, operational definition of what constitutes an ON state versus an OFF state. Therefore, when reference is made to an ON indicator or an indicator that is coded as "ON," the reference implies that the portion of the indicator labeled "ON" has been enhanced with a method of highlighting (e.g., coded with reverse video, colored, enhanced with a check, frame, or reverse video and check). Thus,

"actual" ON/OFF status refers to the experimental manipulation (i.e., addition of highlighting to the "ON" or "OFF" label) and "perceived" ON/OFF status refers to the state that the subject perceives, which may or may not reflect the intent of the experimenter's coding. Thus, the measure of interest is the percentage of agreement among the subjects regarding indicator state.

The indicator state response analysis compared frequency of responses (i.e., "ON" or "OFF") across the five indicator designs. Collapsed across display background, subjects had been presented with 120 indicators highlighting an ON state and 120 indicators highlighting an OFF state for a queried indicator (i.e., PL-1, PL-2, PL-3). In the absence of indicator state confusion, there should be consistency within and across subjects regarding the reported indicator state (i.e., subjects should consistently choose the ON option for all indicators which highlight the ON state and should chose the OFF option for those trials in which the indicator's OFF state is highlighted).

"Confusion" was defined by the number of responses to the non-highlighted indicator option, divided by the number of displays in which the opposite indicator state was highlighted. For example, indicator design confusion was defined as (1) the number of ON responses made to an OFF-highlighted design, divided by the total number of OFF-highlighted displays presented, and (2) the number of OFF responses made to an ON-highlighted design, divided by the total number of ON-highlighted displays presented.

Overall, subjects were consistent in their selections. Across all indicator display designs, when the highlight was applied to the ON section of the indicator, only 1.33 % of the total responses were OFF

responses. Similarly, when the OFF option was highlighted, the ON option was selected only 1.83 % of the time.

Table 1 reports the response frequency pattern for the five indicators, collapsed across the two display backgrounds. The reverse video with check indicator resulted in the least overall state confusion (1.04 %). The highest overall rate of state confusion was obtained with the check indicator (2.29 %).

Table 1. Response frequency as a function of indicator design (collapsed across display background color).

Indicator Design	State Highlighted	Subject Response		Percent State Confusion	Percent Overall State Confusion
		ON	OFF		
Frame	ON	237	3	1.25	1.25
	OFF	3	237	1.25	
Check	ON	238	2	0.83	2.29
	OFF	9	231	3.75	
Color	ON	239	1	0.42	1.25
	OFF	5	235	2.08	
Reverse Video	ON	232	8	3.33	2.08
	OFF	2	238	0.83	
Reverse Video with Check	ON	238	2	0.83	1.04
	OFF	3	237	1.25	

Comparisons of the two display backgrounds show that the overall confusion of indicators was identical (1.59 %) for both the

black and the white display backgrounds. Formal statistical analyses of the state response data were not undertaken due to the small cell sizes. In summary, the indicator state response summary revealed virtually no measurable state confusion for any of the indicator designs. With minimal exposure and training, all designs communicated state information effectively.

3.2 Response Time Analysis

Response time reflects the delay (in seconds) between the onset of the display being monitored and the "ON" or "OFF" response given by the subject. Mean response times as a function of indicator display design and display background are shown in Table 2. The fastest response time was obtained for the color coded indicator, while the slowest was found for the check indicator. Note that response times are slightly faster for black backgrounds than for white backgrounds. A 2 (Background Color) x 5 (Indicator Display Design) within-subjects ANOVA revealed that neither the display background color differences nor the indicator design differences were significant ($F(1,9) = 1.59, p < .24$ and $F(4,36) = 1.59, p < .20$ respectively).

Table 2. Mean response time (RT) as a function of indicator design and display background.

Indicator Design	Display Background		Overall Mean RT
	Black	White	
Frame	2.14	2.12	2.13
Check	2.10	2.18	2.14
Color	2.06	2.13	2.09
Reverse Video	2.09	2.16	2.12
Reverse Video with Check	2.03	2.17	2.10
Overall Mean RT	2.08	2.15	

Note. Mean response times are reported in seconds.

The interaction between the two factors was significant ($F(4,36) = 2.63, p < .05$). This interaction is shown in Figure 3. Simple main effects of indicator design at display background, and display background at indicator display, were not significant ($p < .05$).

The significant interaction may possibly be explained by response time patterns associated with the frame and reverse video with check indicator designs. The fastest response times under one display background were associated with slow response times in the other display background for these indicators. Also, although responses to indicators on black backgrounds were slightly faster than responses to indicators on white backgrounds, the opposite pattern occurred with the frame design.

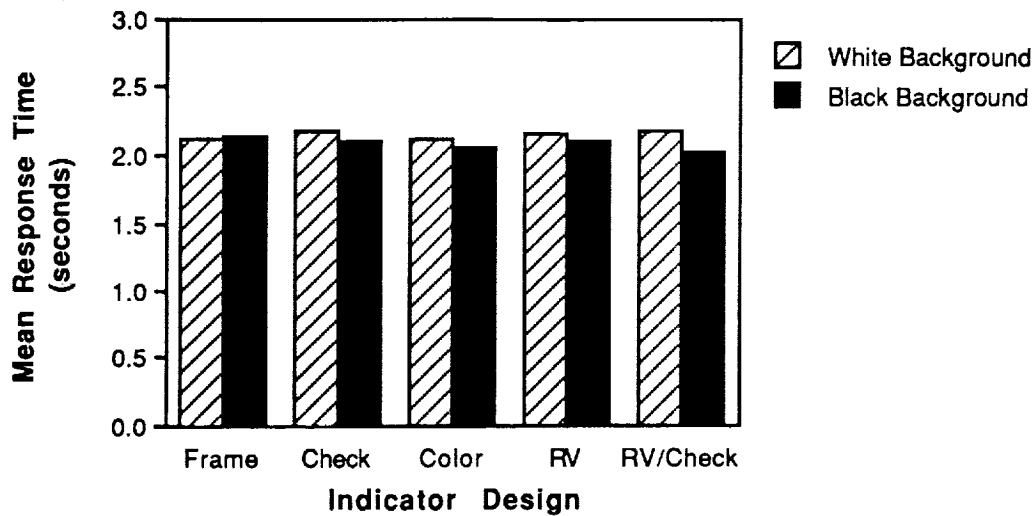


Figure 3. Mean response time (RT) as a function of indicator design and display background.

3.3 Subjective Rating Analysis

Following each block of performance, subjects were asked to rate the effectiveness of each indicator to communicate the ON/OFF state. The scale ranged from 1 (low level of communication) to 10 (high level of communication), with verbal anchors of "low", "medium", and "high" (see Appendix 7.1). The mean ratings of display background and indicator design combinations can be seen in Table 3. Although indicators on white backgrounds were generally judged to be more effective communicators than indicators on black backgrounds (mean subjective judgement: white = 7.01, black = 6.59), the main effect of display background was not significant ($F(1,9) = 2.24, p < .17$).

Table 3. Mean subjective rating as a function of indicator design and display background (the rating scale ranged from 1 [low ability to communicate indicator status] to 10 [high ability to communicate]).

Indicator Design	Display Background		Overall Mean Rating
	Black	White	
Frame	5.80	5.90	5.85
Check	5.00	4.70	4.85
Color	8.85	9.20	9.02
Reverse Video	6.30	7.45	6.88
Reverse Video with Check	7.00	7.80	7.40
Overall Mean Rating	6.59	7.01	

The main effect of indicator design was significant, ($F(4,36) = 10.36$, $p < .0001$). A Student-Newman-Keuls post-hoc test of indicator design collapsed across display background color reveals that the color indicator resulted in significantly higher ratings (mean = 9.02) than any of the other indicator designs. The reverse video with check indicator design was rated significantly higher (mean = 7.40) than the frame and check indicator designs (means = 5.85 and 4.85, respectively), but was not significantly different from the reverse video indicator design (mean = 6.88). The reverse video indicator was not different from the frame indicator, but was rated significantly higher than the check indicator. The least preferred indicator designs, the frame and the check, were not significantly different from each other.

The Indicator Design X Display Background interaction was not significant ($E(4, 36) = 1.27, p < .30$). Mean subjective rating of the indicator designs by display background is shown in Figure 4.

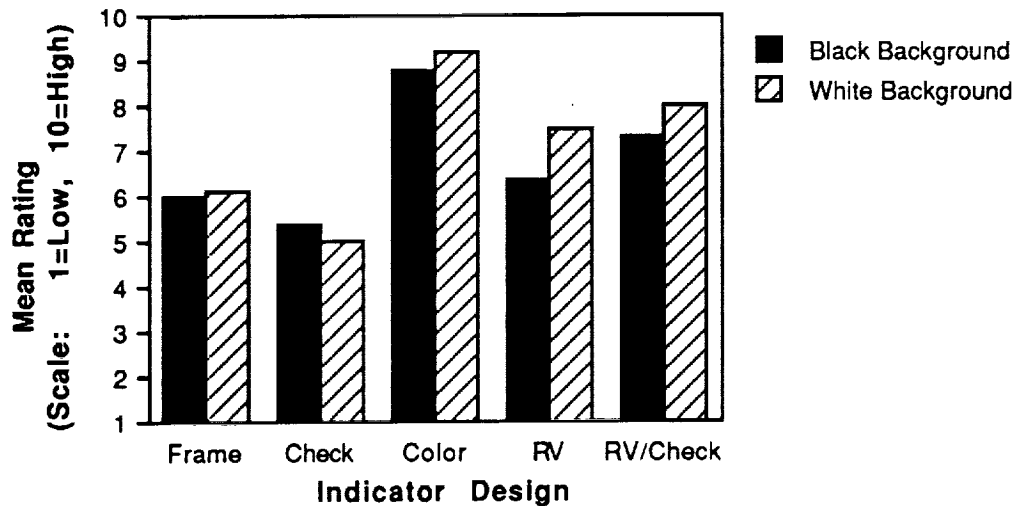


Figure 4. Mean subjective rating of the indicator designs by display background.

3.4 Correlation Analysis

The following analyses were conducted in order to determine whether indicator preference was related to response time differences. Because the background color did not differentially affect either response time or preference, the correlation analyses were collapsed across background color. None of the correlations between indicator rating and corresponding response time for each of the indicators were significant at the $p < .05$ level. The relationship between performance and preference was greatest for the frame indicator ($r = .29$), but the remainder of the indicators had very low correlations between

response time and preference rating (color, $r = -.07$; check, $r = -.06$; reverse video with check, $r = .03$; reverse video, $r = .02$).

4.0 INDICATOR DESIGN DISCUSSION

All of the present data indicate that variations on basic ON/OFF indicator design matters little to actual task performance. The designs in the present study were representative of typical engineering display designs. It appears that any design that reasonably highlights the appropriate state will yield acceptable performance without state confusion. It is also clear that subjective rating of an indicator does not correlate with performance. Three of the indicators merit individual discussion.

4.1 Reverse Video Indicator

Although the present study was initiated as a result of an anecdotal report of indicator state confusion with the use of reverse video indicators, the empirical results do not support the hypothesis that this type of indicator coding results in state confusion. In the present study, while performance with the reverse video condition had the second largest number of confusion errors, this number was virtually insignificant (10 out of 480 judgments). The reverse video indicator fell in the middle range of indicators in terms of response time performance. In terms of the ability to communicate status information, the reverse video indicator was rated next to last in effectiveness. Although significant detriments with the reverse video

coding were not found in this experiment, the trends are in agreement with other human factors literature on reverse video coding. For example, Donner, McKay, Gillan and Rudisill (Ref. 1) found reverse video to be a poor highlighting technique in a search task. In that study, response times to items on complex alphanumeric displays highlighted by reverse video were significantly slower than response times to flashing and color-highlighted items. Present results do not justify a recommendation against the use of reverse video but do suggest cautious, judicious use of this display design.

4.2 Color Indicator

The subjective preference for color without a performance benefit that was found in this study is consistent with other research on color. A study by Tullis (Ref. 5) concluded that color coding was no more beneficial than achromatic shape coding to performance; however, color was viewed by subjects to be pleasing or stimulating. In the present experiment, color was subjectively rated as a better communicator than the other indicator designs, although performance in the color condition was equal to performance in all other indicator design conditions. It is worth noting also that the color coding associated with the indicators was the only use of color on the entire display. Consequently, any effect of color found in the experiment would likely be artificially elevated due to the saliency of the color code. The subjective ratings of the helpfulness of color may have been influenced by its saliency in the present context. In typical real-world

displays, color is often used throughout the display, diluting the attention-attracting value of color.

4.3 Reverse Video with Check Indicator

The expected overall redundancy advantage for the reverse video with check condition was not found. In addition, it is unclear why there would be a redundancy effect for the black background and not for the white background. In terms of subjective preference, the reverse video with check condition was rated in the middle range of effectiveness as an indicator.

This redundant indicator may be of value in situations where there are multiple uses of reverse video on the display. In general, however, given the extra display "real-estate" needed for this indicator, there is little justification for recommending it over and above the other indicators.

5.0 OVERALL DISCUSSION

The environments that incorporate ON/OFF indicators into their human-computer interface are typically those in which emphasis is placed on the accuracy of judgments and actions rather than on the speed of judgments and actions. Consequently, the reliability of perception of an ON/OFF indicator is of utmost importance. State confusions of binary indicators can have especially grave consequences. The present data reveal that all of the indicators presented, including those that mimic the hardware/paper equivalent and those that do not,

produce equal user performance. With the minimal training given in this experiment, subjects had no trouble interpreting the state of the indicators and performed status decisions with equal speed. There still remains the possibility that more performance differences would have been seen with increased task difficulty. The present task was extremely simple, required little training and was basically a one-step recognition task. If several such recognitions or complex decisions based on the indicators were required, it is possible that greater performance differences among the indicator designs would have emerged.

In addition, it is possible that a highly colorful and/or dense display would either negate the benefit of the single color highlight or dilute the salience of the indicators and alter the results found in the present study. One hypothesis for failing to support the anecdotal reports of state confusion could be related to variations in brightness level. During subsequent review of the Space Station prototype display which was the impetus for the present study, it was noted that the white ON/OFF highlight seemed noticeably brighter than the other colors. It is unclear whether this effect was caused by such factors as facility lighting or display monitor settings. Under these conditions, the anecdotal reports of confusion of indicator state may be attributed to conflicting highlighting (e.g., brightness coding of the white highlight competing with the black and white reverse video coding). This would result in the reported state confusion and could be another reason to be cautious about the use of reverse video.

Unfortunately, display design is generally taken for granted until there are catastrophic errors or complaints from the users. With the

growing number of software interfaces that represent hardware components, the problem of representing hardware components via software will become increasingly pervasive. Much more research needs to be performed on the design of software representations of hardware. The present research is one step in that direction.

6.0 REFERENCES

1. Donner, K. A., McKay, T., Gillan, D. J., & Rudisill, M. (1990, April). *The effects of display format, highlighted item and highlighting technique on search/identification tasks*. Interactive Poster presented at the CHI '90 Conference on Human Factors in Computing Systems, Seattle, WA.
2. National Aeronautics and Space Administration. (October, 1989). *Man-systems integration standards* (NASA-STD-3000, Vol. 1, Revision A). Washington, DC: National Aeronautics and Space Administration.
3. Schwartz, D. R. (1988). The impact of task characteristics on display format effects. *Proceedings of the 32nd Annual Meeting of the Human Factors Society*, 352-356.
4. Shneiderman, B. (1987). *Designing the user interface: Strategies for effective human-computer interaction*. Reading, MA: Addison-Wesley.
5. Tullis, T. S. (1981). An evaluation of alphanumeric, graphic, and color information displays. *Human Factors*, 23, 541-550.

7.0 APPENDIX

7.1 Indicator Rating Forms

Black Display Background

On a scale of 1 to 10, rate the ability of each indicator to communicate the 'ON/OFF' status. NOTE: These indicators are on a black background.

✓

ON
OFF

 ✓

ON
OFF

 ✓

ON
OFF

1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	----

low medium high

✓

ON
OFF

 ✓

ON
OFF

 ✓

ON
OFF

1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	----

low medium high

ON
OFF

ON
OFF

ON
OFF

1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	----

low medium high

ON

OFF

OFF
OFF

1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	----

low medium high

ON
OFF

ON
OFF

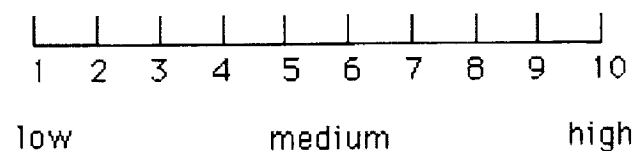
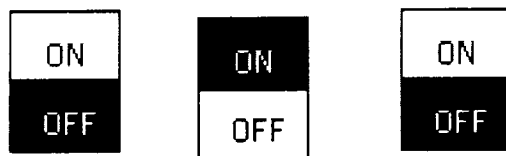
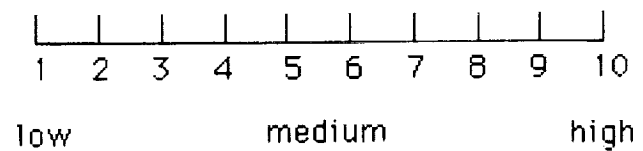
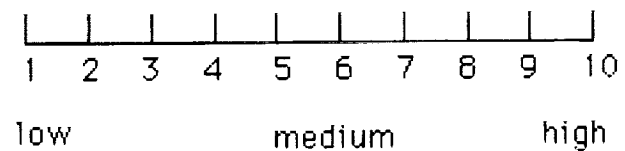
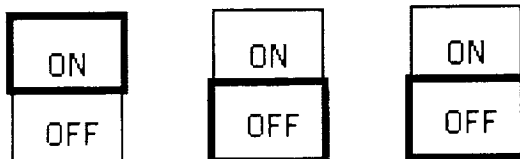
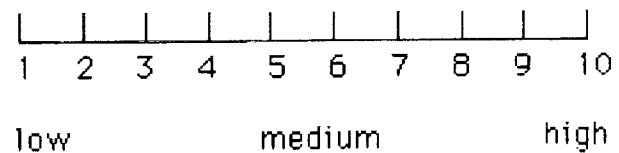
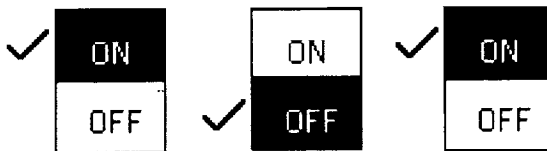
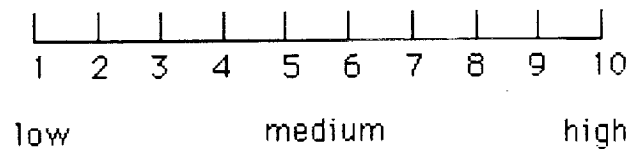
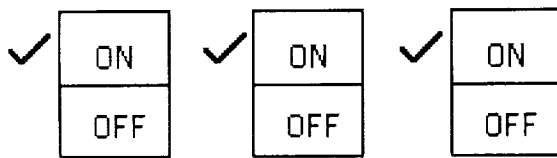
ON
OFF

1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	----

low medium high

White Display Background

On a scale of 1 to 10, rate the ability of each indicator to communicate the 'ON/OFF' status. NOTE: These indicators are on a white background.



7.2 General Questionnaire

General Questionnaire

Subject Number: _____

Sex: _____

Which display screen background color do you prefer? Black _____

White _____

Have you ever seen or used a computer display with 'On'/'Off' indicators?

Yes _____

No _____

What kind of computer do you typically use?

IBM _____

Macintosh _____

Can you think of any other indicators that could communicate 'On'/'Off' state information?

REPORT DOCUMENTATION PAGE

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13. ABSTRACT (Maximum 200 words) This study investigates five designs of software-based ON/OFF indicators in a hypothetical Space Station Power System monitoring task. The hardware equivalent of the indicators used in the present study is the traditional indicator light that illuminates an "ON" label or an "OFF" label. Coding methods used to represent the active state (i.e., "ON" or "OFF") were reverse video, color, frame, check or reverse video with check. Display background color (i.e., black, white) was also varied. Subjects made judgments concerning the state of indicators that resulted in very low error rates and high percentages of agreement across indicator designs. Response time measures for each of the five indicator designs did not differ significantly, although subjects reported that color was the best communicator. The impact of these results on indicator design is discussed.					
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